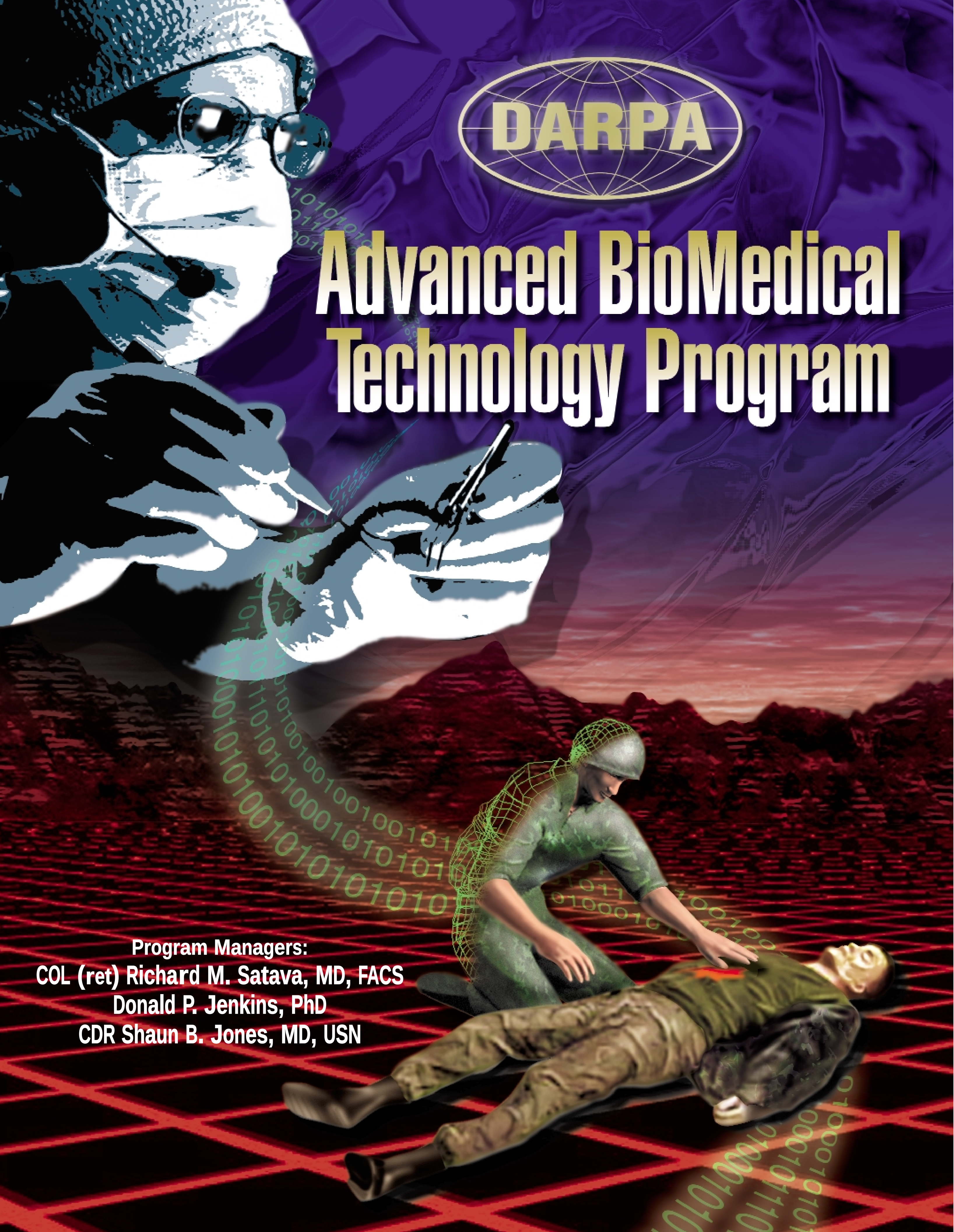


Advanced BioMedical Technology Program

Program Managers:
COL (ret) Richard M. Satava, MD, FACS
Donald P. Jenkins, PhD
CDR Shaun B. Jones, MD, USN

FOREWORD

The Advanced Biomedical Technologies (ABMT) program was the first recent Defense Advanced Research Projects Agency (DARPA) program in the healthcare field. DARPA conceived the program in 1993 in response to emerging medical technologies that we felt could provide far-forward medical care to combat casualties. We applied DARPA's expertise in robotics, microelectromechanical systems (MEMS), informatics and virtual reality to biosensors and imagers for diagnosis, telesurgery systems for advanced surgery, and simulation for combat medic and surgical training. The ABMT program that we developed was integrated and comprehensive and focused on technologies to save the wounded soldier in the far-forward battlefield.

The ABMT program used an innovative dual-use approach that concentrated on technologies useful to civilian medical care as well as to the military. The program could therefore accelerate technology transfer and reduce the overall cost to commercialize the products that the military needed. We made a conscious effort throughout the ABMT program to move technologies out of the laboratory and into practical daily use both in the battlefield and in civilian hospitals.

This report is a testimony to all of the principal investigators who have worked so hard and accomplished so much to advance medical care for our warriors. The technologies developed by the ABMT program are just the beginning of a revolution in combat casualty care, and are providing a strong foundation for 21st century medical practices.

Jane A. Alexander
Deputy Director

DARPA

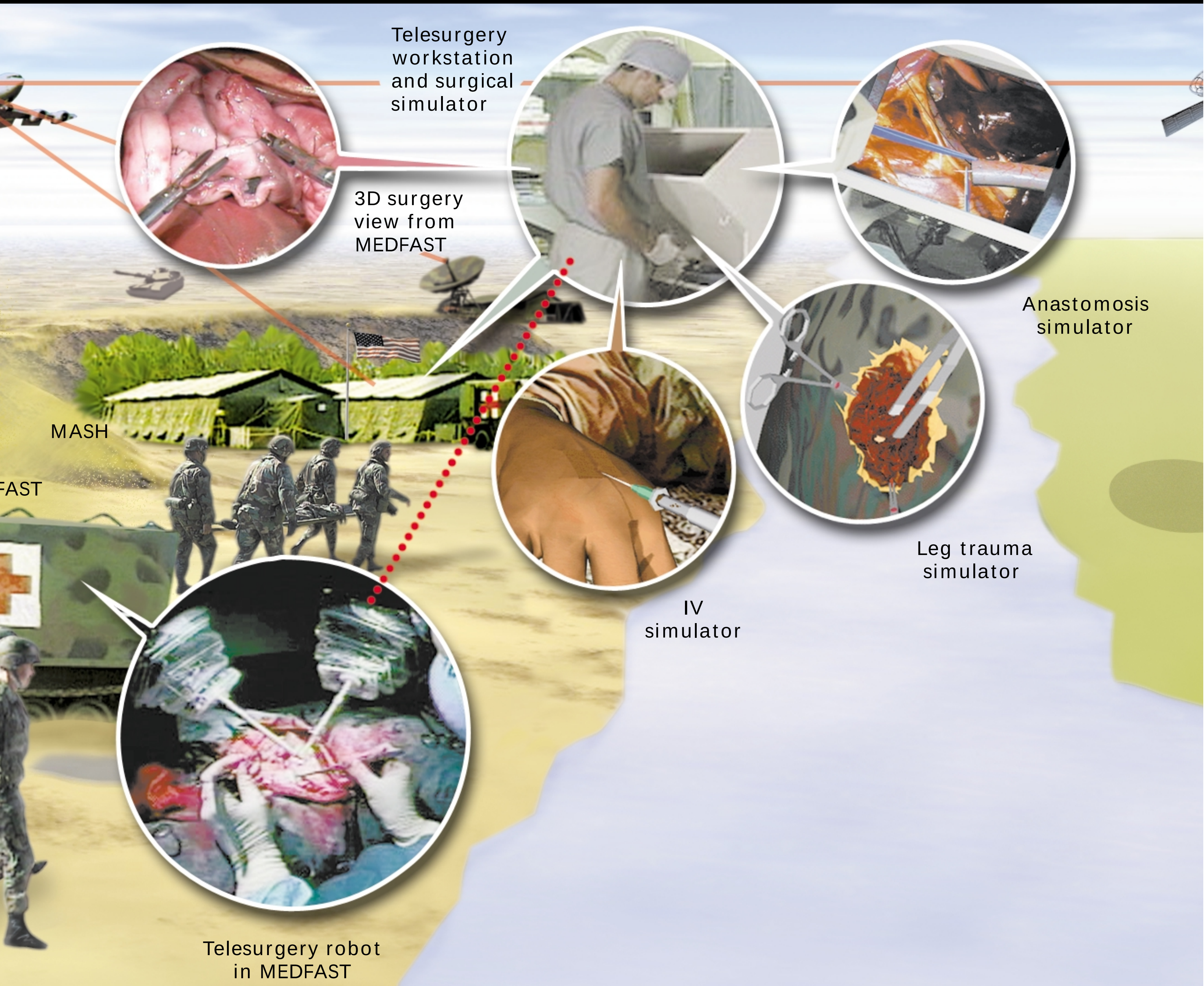
Advanced BioMedical Technology Program

Theater of War

Real World—Diagnosis and Treatment

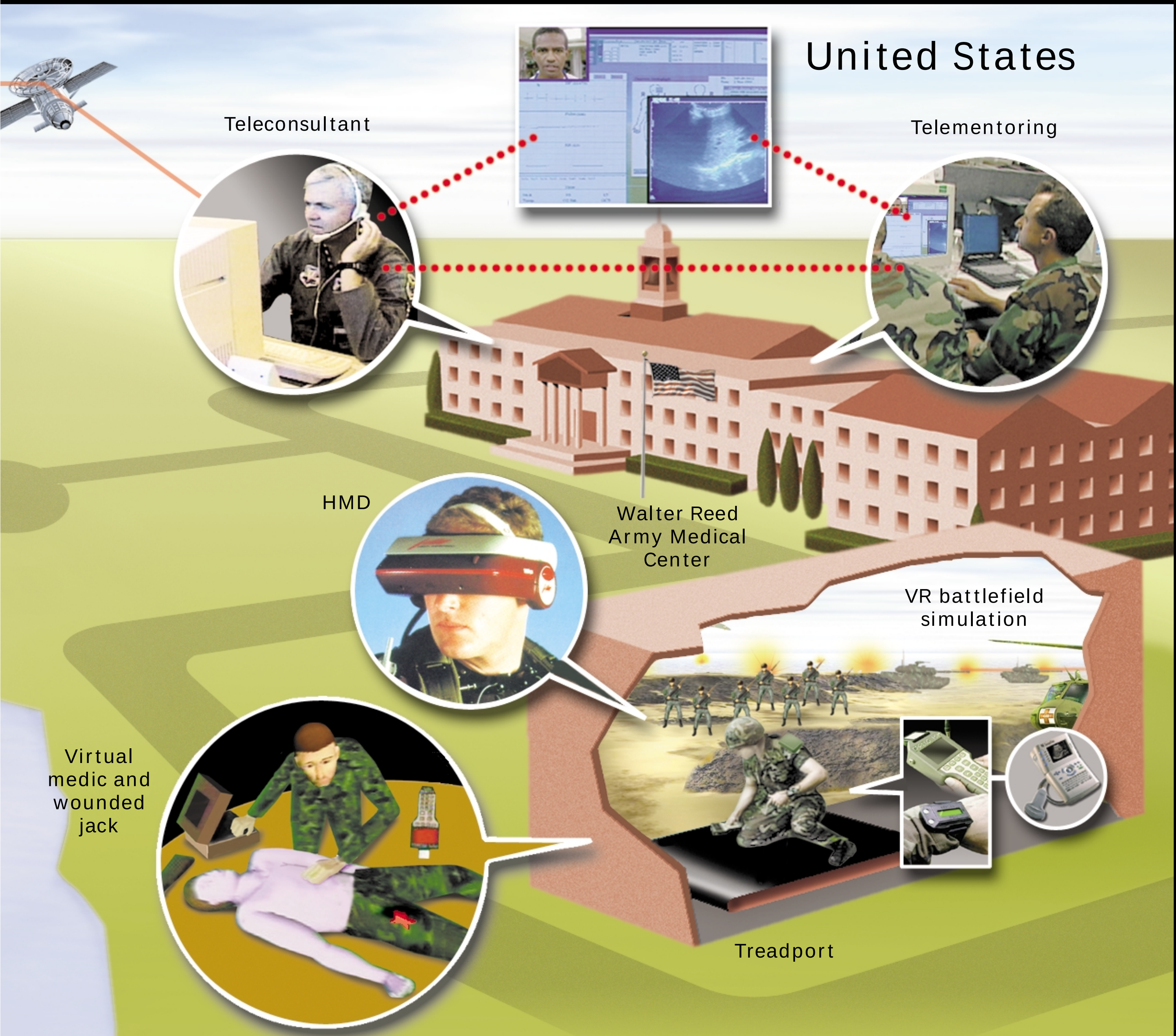
This illustration depicts the principle concepts underlying the DARPA Advanced BioMedical Technology (ABMT) Program. To improve combat casualty care, applications in both real and virtual worlds were integrated. The ABMT program can be best explained by the following scenario.

Each soldier wears a Personnel Status Monitor (PSM) system which monitors vital signs and location. When the soldier is wounded this information is automatically transmitted to the closest medic, allowing the medic to determine the severity of injury and location of the soldier. A hand-held ultrasound can determine if internal injuries have occurred. If the soldier can be stablized, he is placed into a Life Support for Trauma and Transport (LSTAT), which is an intensive care unit (ICU) miniaturized to fit within a stretcher. All capabilites of an ICU, including ventilator, IV fluid pump, resuscitation system, as well as telemedicine are incorporated. This allows the surgeon at the Mobile Advanced Surgical Hospital (MASH) to remotely monitor and treat the casualty during evacuation. If the soldier's wound is so severe that he will bleed to death before arriving at the MASH, the casualty is placed into the Medical Forward Advanced Surgical Technology (MEDFAST) vehicle, which is an armored transport with a telesurgery system installed. Together, the medic in the MEDFAST can assist the surgeon located back at the MASH to perform surgery to stop the exsanguinating hemorrhage. Once stabilized, the casualty is placed into the LSTAT and evacuated back to the MASH where the waiting surgeon will complete the surgery on the wounded soldier. The information is available throughout the battlefield and to upper echelons through a telemedicine network, both for teleconsultation in real time as well as to commanders for planning, logistics and coordination.



DARPA

Advanced BioMedical Technology Program



Virtual World Applications: Education & Training

Education and training is an integral part of every soldier's preparedness. A soldier trains as he fights, and fights as he trains. For the medic, a full training program using Virtual Reality (VR) to simulate the real world was instituted by the DARPA ABMT Program. It follows the real scenario above, but incorporates the newest simulation technologies.

Using a treadmill or "Treadport", the medic "walks through the battlefield" with the other virtual warriors. A head mounted display (HMD) provides the battlefield scene. When a virtual soldier (Jack) is wounded, the medic "treadmill runs" to the casualty. Reaching the casualty, the treadmill stops, and the medic makes the diagnosis and simulates treatment (such as chest tube placement for a pneumothorax). Once stabilized, the virtual casualty is placed in the virtual LSTAT and then evacuated.

Other components of the ABMT program include VR partial task trainers for wound debridement and hemorrhage control (Leg Trauma Simulator), starting IV fluids (IV Simulator) and suturing anastomoses (Anastomsis Simulator). These trainers supplement the medic's skills required to perform the virtual scenario, and more importantly, real world applications. VR skills training is imported into the diagnostic and therapeutic devices, such as the ultrasound and telesurgery systems.

VR FOR EDUCATION AND TRAINING

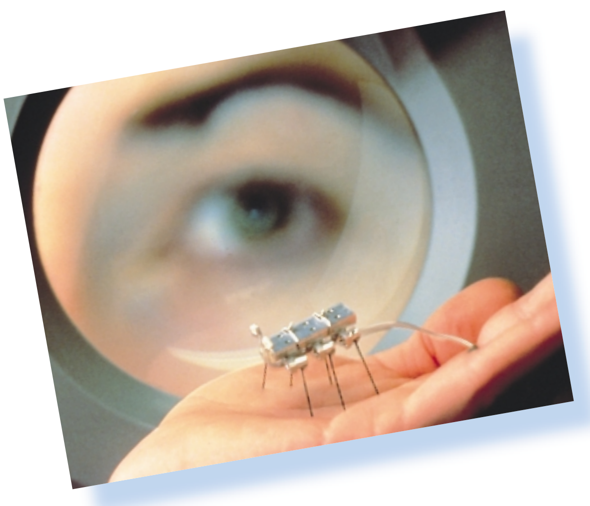
SUPPORT TECHNOLOGIES

* SBIR/Feasibility

PREFACE

The fundamental revolution of the Information Age is the concept of working with information (bits) instead of actual objects (atoms). This was one of the primary lessons learned from the Gulf War. Working in the "information world" permits integration of seemingly incongruous devices into a single harmonious whole. During a 1995 National Academy of Science study there was an informal analysis of how much of healthcare can be represented as information (bits instead of atoms). On the battlefield, the medic uses an ultrasound (digital image) to diagnose an internal injury and transmit the image using telemedicine. During laparoscopic (video) surgery on the casualty, the surgeon is looking at the video monitor (information) instead of the actual organs (atoms). When surgery is complete and the casualty is being checked in the recovery room, the surgeon looks at the vital signs monitor before taking the pulse (information equivalent of the sense of touch). The medical record is becoming electronic, and the use of virtual reality for surgical training exploit the information technologies. All of the above capabilities can be implemented using telemedicine and the internet.

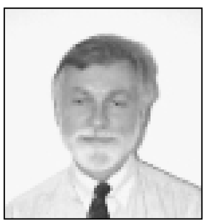
Another key element in information technologies is the 3-D digital image of an individual. Once such an image is acquired with computer tomography (CT scan), magnetic resonance imaging (MRI) or ultrasound, this image can be reconstructed in three dimensions and be utilized for the many critical medical actions. The image can be vn through" for diagnosis (called virtual endoscopy), be used for operative planning of a difficult case, imported during surgery intra-operative navigation, and archived in a surgical simulator education and training. As the model becomes more realistic, it n be used for testing the effects of non-lethal weapons. The nage can also be exported over the internet in real-time for conultation in telemedicine.



Reduction of the real world into the information world (data acquisition through diagnostic sensors and imagers), processing of the information (databases and telemedicine), and returning the information to the real world (3-D displays and theraputic devices) not only integrates the entirety of healthcare, but extends the capabilities beyond phyiscal limitations. Seeing body (ultrasound), operating at a distance (telesurgery) and care (virtual reality simulators) are but a few examples of information technology providing capabilities not previously possible. These underlying concepts drive the projects that comprise the overall ABMT program.

Richard M. Satava, M.D., FACS

Professor of Surgery at Yale University School of Medicine, Professor of Surgery at the Uniformed Services University of Health Sciences (USUHS) and Special Assistant at US Army Medical Research and Materiel Command. Undergraduate training was at Johns Hopkins University, medical school at Hahnemann University of Philadelphia, internship at the Cleveland Clinic, surgical residency and fellowship (MS in Surgical Research) at Mayo Clinic. During 20 years of military surgery he has been a flight surgeon, an Army astronaut candidate, MASH surgeon for the Grenada Invasion, and a hospital commander for Desert Storm. He was on the White House Office of Science and Technology Policy (OSTP) subcommittee of Health, member of numerous committees of the American College of Surgeons (ACS) and National Board of Medical Examiners (NBME), Board of Governors of many surgical societies, editorial board of numerous surgical and scientific journals, and active in surgical and engineering societies. He continues to be active in surgical education and surgical research with over 150 publications and book chapters in diverse areas of advanced surgical technology.



Donald P. Jenkins, Ph.D.

Dr. Jenkins holds a senior executive position at the National Institutes of Health as Resident Anatomist, National Library of Medicine, Lister Hill National Center for Biomedical Communication, with the Visible Human Project, Telemedicine, and Next Generation Internet programs. Received a Doctorate, University of Washington School of Medicine; joined the faculty, Georgetown University Schools of Medicine and Dentistry; was consulting anatomic Editor, CIBA/Netter CIBA Collection; was Adjunct Associate Professor, Surgery, Georgetown University, and is; Visiting Professor of Anatomy, Uniformed Services University of the Health Sciences, Bethesda. In 1986, invited by the Army's Surgeon General co-founded the Textbook of Military Medicine as one of three series Editors of the seventeen volume series. In 1992, Dr. Jenkins was founder and Director of the Surgeon Generals Borden Institute, Walter Reed Army Medical Center—a "think-tank" for issues of combat casualty care. In 1992 was assigned to the Defense Advanced Research Projects Agency (DARPA) by the request of the Army Surgeon General, and Director, Defense Research & Engineering (DDR&E) as Special Assistant to the Director of DARPA, and Deputy Director of the DARPA's Defense Sciences Office.

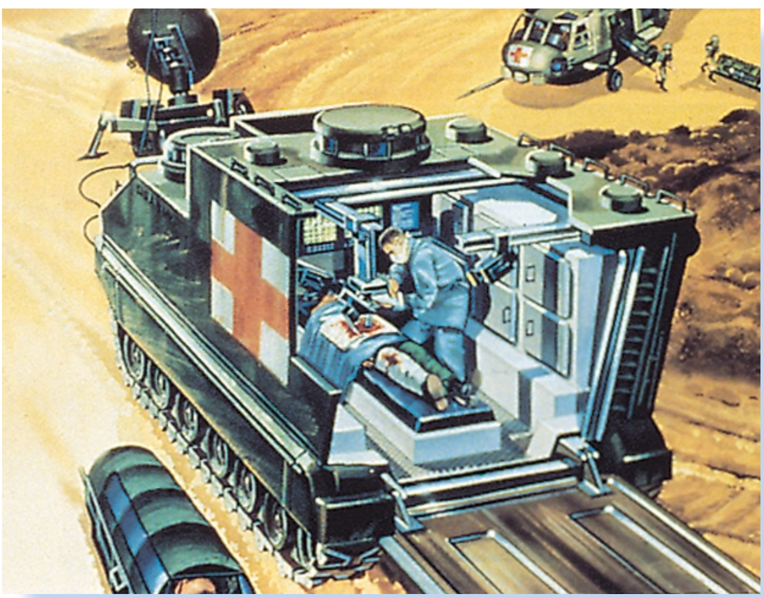
CDR Shaun B. Jones, M.D., USN

Dr. Shaun B. Jones is a Project Officer for the National Reconnaissance Office (NRO). Prior to this assignment he was the Program Manager for Unconventional Pathogen Countermeasures in the Biological Warfare Defense Program at the Defense Advanced Research Projects Agency (DARPA).

Dr. Jones is an active duty Commander in the United States Navy and Assistant Professor of Surgery at the Uniformed Services University of the Health Sciences. Dr. Jones earned his medical degree at the Uniformed Services University of the Health Sciences. He completed a residency in Otorhinolaryngology-Head and Neck Surgery at the National Naval Medical Center and was a resident research fellow in the Divisions of Cytokine Biology and Monoclonal Antibodies, Center for Biologics Evaluation and Research of the Food and Drug Administration (FDA) . Dr. Jones is a Diplomate of the American Board of Otolaryngology, a Fellow of the American Academy of Otorhinolaryngology - Head and Neck Surgery, Honorary Member of the American Academy of Facial Plastic and Reconstructive Surgery (AAFPRS) and a FDA Consultant, Division of Ear, Nose and Throat Device Evaluation. In addition to numerous chapters and publications, Dr. Jones is an internationally invited speaker and active participant on multiple editorial boards for peer reviewed journals on advanced medical and surgical technologies as well as biological warfare defense. He has operational experience in Naval Undersea and Surface Warfare, as well as Special Operations, and is a regularly invited consultant to a variety of DoD visioning panels.

INTRODUCTION

The Advanced BioMedical Technologies (ABMT) program was a highly integrated program that sought to exploit advanced information age technologies to dramatically improve combat casualty care in the far forward battlefield. A review of the past 200 years of battlefield casualties had revealed that, in spite of significant medical advances, the mortality rate in the far forward battlefield had remained essentially unchanged. An analysis of the Viet Nam Wound Data and Munitions Effectiveness Tables (WDMET) database provided insight into the fact that, of the soldiers that died of wounds, over 40% died with injuries from which they could be saved had medical care been provided, with over half dying of uncontrolled hemorrhage. It also became apparent that improvement could not occur without the full spectrum of medical care in diagnosis, therapy and education/training. Providing a new diagnostic capability would not increase survival without concommitant advanced therapeutics, as well as the education and training to use the new devices and technologies. Thus the program management consisted of integrating a number of disparate technologies into a unified whole with the focus being the wounded soldier.



The ABMT program was also unique in that it was one of the first programs to be incorporated into the Technology Reinvestment Program, later to be known as Dual Use Program. These programs placed high priority on collaboration among academia, government and industry, frequently requiring matching funds from commercial partners. The overall goal was to reduce cycle time and accelerate technology transfer from laboratory to commercial product by involving industry partners. This provided an exceptional challenge, for the program included early discovery (basic science) projects along with more mature research (applied science) that leveraged non-medical discoveries into healthcare. Finally, there was the requirement that the projects which comprised the program must be applied to both military and civilian applications.

This final program report is an attempt to capture the 5 years of research and development, both successes and failures, as well as a portfolio of technologies which have progressed to a point that they are available for either further technology transfer into the military inventory or as commercial products which are available to the military as commercial over-the-counter (COTS).